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DIFFERENCES IN THE RATES OF RETURN TO R&D FOR EUROPEAN AND US YOUNG LEADING R&D FIRMS

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Abstract

This paper examines the sources of Europe's lagging business R&D performance relative to the US, particularly the role played by missing young leading innovators in high technology intensive sectors in Europe. It investigates through econometric analysis differences in the rates of return to R&D of European and US large R&D firms. It finds that, while in the US, young firms succeed in realizing significantly higher rates of return to R&D as compared to their older counterparts, including in high-tech sectors, European firms fail to generate significant rates of return, even if they are yollies and even if they are in high-tech sectors. These findings can at least partly explain why Europe has less R&D intensive young leading innovators in high technology intensive sectors.

Key words: young firms, rate of return to R&D, EU-US R&D gap

JEL codes: O33

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1. Introduction

Innovation in the European Union remains weak, especially R&D investment by the business sector. Furthermore, there are relatively few signs of progress despite the 3% Barcelona target which was set in 2000 (European Commission, 2012).

A common explanation raised for the EU's tame business R&D performance is its failure to change to new areas of growth. At the sectoral level, the EU continues to specialize in medium-tech sectors, lacking strong positions in new high-technology sectors. The EU is especially lagging in new key information technology sectors, which were the drivers of growth in the late 1990s in the US (eg Van Ark et al 2008; Denis et al., 2005; European Commission, 2007; Moncada et al., 2010). It also lagged behind in the use of ICT technologies for productivity enhancing investments (eg Van Ark et al 2008), related to a.o. shortcomings in management and organisational practices in European firms (Bloom & van Reenen, 2010).

It is particularly fast growing technology based entrants which are key players in the industrial dynamics of economies. Cohen and Lorenzi (2000) already argued that the US economy is a more hospitable environment than the EU for new firms to grow large in Information Technology. Also Freeman (2001) acknowledged that ICT was more successful in the US than anywhere else, which he attributes to the outstanding characteristics of the US national innovation system: the role of new small firms in the American economy, the role of the US government (both at Federal and State level) and the role of universities. Mowery and Rosenberg (1993) in their analysis of the United States national innovation system emphasised that 'the successive waves of new product technologies that have swept through the post-war US economy … have been commercialised in large part through the efforts of new firms', this in sharp contrast with European countries and Japan (Mowery and Rosenberg (1993, pp. 48–49)). They point out that 'the large basic research establishments in universities, government and a number of private firms served as important 'incubators' for the development of innovations' which were commercialised by individuals who 'walked out of the door' to become innovative entrepreneurs.

New firms are particularly pivotal in the early stages of development of new sectors, being the drivers of "creative destruction" in the Schumpeter Mark I model (Klepper, 1996, Malerba, 2002). It is only when new sectors have achieved a high rate of growth for a long time before they have a big enough weight and a strong enough influence on other sectors to adapt to the innovations, that they start to drive the overall economy's performance (Freeman & Louça, 2001). Nevertheless, with young leading innovators being more (radical) R&D intensive and/or their presence inciting other (incumbent) firms to be more (incremental) R&D intensive, a nation that fails to generate new innovative firms and let them grow to a worldwide leading R&D position, will eventually suffer in terms of its overall innovative capacity.

The proposition that Europe's deficient innovative capacity is driven by a failing creative destruction capacity, missing young innovators and new sectors, has attracted many supporters (O'Sullivan, 2007). But it has received little empirical investigation. Agion et al. (2008) provide firm level evidence in support of the proposition that Europe has less productivity gains from fast growing technology based entrants, compared to the US. In a recent contribution, Cincera and Veugelers (2013) use the EC-JRC-IPTS Industrial R&D Scoreboard (European Commission, 2008) of largest global R&D spending firms to compare the sectoral and age composition of EU business R&D performance relative to the US. Their findings confirm that the EU has fewer young firms among its leading innovators, called "yollies". Furthermore, European "yollies" have a lower R&D intensity than their US counterparts, being less in new high technology intensive sectors. They find that missing 'yollies' in the right sectors accounts for almost all of the EU's overall business R&D deficit relative to the US.

This paper tries to answer why there are less young leading innovators ("yollies") in Europe compared to the US, particularly in high-tech sectors, and why they would invest less in R&D, as documented in Cincera & Veugelers (2013). It looks at differences in rates of return on R&D investments as a possible explanation. To this end, an econometric analysis is performed, estimating production functions for the largest global R&D spending firms. The findings confirm, while in the US, young firms succeed in realizing significantly higher rates of return to R&D as compared to their older counterparts, including in high-tech sectors, European firms fail to generate significant rates of return, even if they are yollies and even if they are in high-tech sectors. These results would suggest that in order to nurture more young new firms in young high-tech sectors, as pivotal agents of a dynamic business R&D structure, the barriers that lower the rates of return to R&D for these firms need to be better understood and addressed.

After a review of the literature on young innovative companies in Section 2, Section 3 presents the data being used in the econometric analysis. Section 4 presents our econometric findings on differences in rates of return to R&D for young leading innovators in the EU versus the US. A final section summarises and discusses policy implications of our findings.

2. Young companies and R&D: insights from the literature

The innovation literature provides multiple points of view as to why having young firms might matter for an economy's R&D performance. Dating back to Schumpeter, young entrepreneurial firms are at the heart of the creative destruction process (Schumpeter, 1934; the so-called Schumpeter Mark I). Young entrepreneurial firms are more likely to be introducing innovations, particularly of the radical type, displacing existing products and processes. This is because young, small, lenient firms, unlike their large incumbent counterparts are not bothered by safeguarding incumbent positions and suffer less from bureaucratization of the innovation process. With new firms entering with new technology or focusing on new types of demand, a stable innovation structure characterized by large incumbents (Schumpeter Mark II) may be displaced by a more turbulent Schumpeter Mark I ((Reinganum 1983; Henderson and Clark, 1990). The introduction and further diffusion of new technologies brings about a crisis of structural adjustment in which the incumbent institutions are challenged to adapt their framework to a system more compatible with the new rising technology (Perez, 2010). These changes may take a long time, as they require new infrastructure, new standards, changes to education and training for new skills, new management and organisational systems (Freeman & Louça, 2001).

At the same time, arguments abound on why large incumbent firms are the driver of innovations (Schumpeter, 1943; Schumpeter Mark II). Large incumbent firms can benefit from economies of scale and scope in the R&D process and complementarities with other competences needed to commercialize the innovations. Large incumbent firms can benefit from learning by doing, having accumulated experience to drive down costs (Malerba, 1992). With higher liquidity at their disposal and collateral, they have easier access to finance (Cincera and Ravet, 2010). Small and particularly young firms, lacking internal funds, collateral and reputation are more likely to be financially constrained, particularly if they are looking to finance high growth-high risk projects (Cincera, 2003; Hall and Lerner, 2010). Large incumbent firms may also find it easier to appropriate the benefits from innovation, having the scale for developing a portfolio of appropriation strategies (Schneider and Veugelers, 2012) and complementary assets (Teece, 1986; Gans and Stern, 2000). And finally, the threat of entrants may spur incumbent's innovations, motivated by the fear of being displaced (Gilbert and Newbery, 1982).

Large incumbents and small entrants should not only be seen as direct competitors. Both types of firms can also complement each other in the innovation eco-system. Small new entrepreneurial firms introduce new drastic innovations on which the large incumbent firms build further with their follow-up innovations, thus further improving and developing the full potential of these innovations. How effective the market for ideas is, where large incumbent firms take on and further develop the ideas launched by young innovators, depends inter alia on the strength of the intellectual property protection (Anton & Yao 1994) and the control over complementary assets (Gans and Stern 2000; Gans et al., 2002). When the new ideas eventually mature and start following well defined trajectories, economies of scale, learning curves, barriers to entry and financial resources become important in the competitive process (Klepper 1996)), thus favouring large firms with deeper pockets: large incumbent firms or new firms grown to critical size.

Overall, with arguments in favour as well as against young innovators, it remains an empirical question to identify whether, when and how young firms will be more innovative than large incumbent firms.

Much of the multivariate empirical analysis in the literature studying the relationship between firm size, age and innovation, incorporating a wide set of firm and industry characteristics as control, has failed to find significant results for a positive (or negative) effect of firm size and age (Kamien and Schwartz, 1982; Cohen and Levin, 1989). Other characteristics like market concentration, technological opportunities, the stage of the technology life cycle, all matter as intervening variables for the effect of firm size and age for innovation. Small young firms are more important for innovation in less concentrated industries (Acs and Audretsch, 1987) and in the early stages of the life cycle of an industry (Utterback, 1994).

When it comes to radical innovations, there is more support to be found for small, new firms compared to large incumbents. Henderson (1993) examined two theories of why large incumbent firms fail to create radical innovations: (1) lack of motivation (the economic perspective), and (2) lack of ability (the organizational perspective). Her analysis, using data from the semiconductor photolithography equipment industry, showed support for both theories. Shane (2001) similarly finds evidence in favor of small firms introducing radical innovations. His research on MIT based patents finds that radical patents have a higher probability that the invention will be commercialized through start-ups. Schneider and Veugelers (2010) provide micro-econometric evidence from German CIS data in support of young, small highly-innovative companies (YICs) for the introduction of more radical innovations. Controlling for other firm and industry characteristics that might explain innovative performance, they find that YICs achieve on average a higher level of innovation performance than other innovators. This difference is substantially more pronounced for the measure of sales with market novelties, suggesting that young highly-innovative firms are most differentially successful when it comes to introducing more radical innovations. Pellegrino et al. (2011) using Italian CIS data find young innovative companies to rely more on embodied technical change from external sources to drive their more radical innovation projects.

When it comes to the growth process of new innovators, the empirical analysis of the growth performance of new technology based firms identifies a mixture of firm, founder, founding team and environment characteristics to be of relevance for explaining post-entry growth (Almus and Nerlinger, 1999; Acs and Audretsch, 1990). There is firm age (Jovanovic, 1982), start-up size (Evans, 1987), the education and experience of the founder and founding team (Colombo and Grilli, 2005), partnerships with other innovation actors, local agglomeration effects among others. An important barrier for growth identified in the literature is the presence of liquidity constraints, as shown by the impact of start-up capital, internal funds and the availability of external financing, in casu most notably venture capital backing (a.o. Bertoni et al., 2011).

3. Data Set and Descriptive Statistics

If the EU has less young leading innovators, less radical young leading innovators and less in new high-tech sectors, as documented in Cincera & Veugelers (2013), why is this so? Is this because young firms have fewer incentives to invest in R&D as compared to their US counterparts? Do young leading innovators have lower rates of returns to their R&D investments in Europe compared to the US?

This paper contributes to these questions by econometrically assesses any differences in the rates of return to R&D by region and age of leading innovating firms. To estimate rates of return to R&D we use the set of firms which belong to the European Union (UE)-1000 and non-EU-1000 largest[2] R&D spenders in the 2010 edition of the EU-JRC-IPTS Industrial R&D Investment Scoreboard[3]. The dataset also contains information on the following variables: main industrial sector (according to the Industry Classification Benchmark, ICB), country of origin of the firm, net sales, number of employees, and R&D investment for each year of the period 2004-2009.

This data set has been augmented with information on the age of the creation of firms, allowing to distinguish between young and old firms [4]. Young firms identified are not *small* start-ups. They are a group of firms that managed on their own, i.e. without being taken over, in a relatively short time span since birth, to grow to a world scale leading position deploying substantial R&D resources. These firms have managed to overcome not only any barriers to entry but also barriers to growth to world leading innovator status. Indeed, the average size for the young firms is 10,000 employees worldwide. The dataset of world leading innovators is not suited to check for a start-up or SME dimension as it includes (almost) no firms with less than 250 employees.

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[2] Large firms are companies with R&D investments higher than 35 millions € in 2007.

[3] The European Commission JRC-IPTS collects since 2004 annual data on companies investing the most in R&D worldwide (the EU Industrial R&D Investment Scoreboards).
See: http://iri.jrc.ec.europa.eu/research/scoreboard.htm

[4] The sources used for retrieving the age information are mainly the websites of companies (86.0% of firms) and Wikipedia (78.7%). These sources have been crosschecked with the Amadeus database (for the EU companies only, 25.6%), the dataset of Veron (2008) which is publicly available[4] (9.6%) and other sources (less than 10% of firms) such as Business Week, FinanceYahoo, LinkedIn. To construct the age of the firms we use the very first year of the firms' creation, i.e. ex-nihilo creation. In case of a merger and acquisition (14.9% of the cases), the oldest age of the merged entities is considered.

Due to missing data for some firms, the final sample includes 1034 firms. The data set is representative of 96.1% of the R&D carried out in 2007 by the top 2000 worldwide corporations' listed in the EU-JRC-IPTS 2008 industry R&D Scoreboard which is itself representative of more than 80% of the worldwide R&D in the private sector (Business Entreprise R&D)[5]. 29% of our sample firms are from the EU, 38% from the US, 19% from Japan and 14% from the Rest of the world.[6]

We define young companies as the ones that were created after 1975. We label them as **young leading innovators (Yollies)** compared to **old leading innovators (Ollies)**. We have 363 Yollies, i.e. 34% of our sample. Sixteen percent are 'very young', i.e. born after 1990. Yollies are typically smaller in size, employment and R&D budget than Ollies, but they are more R&D intensive: the average R&D intensity of Yollies is 6.3 percent compared to 3.2 percent for old firms, almost twice as high.

A number of industry and services sectors are particularly associated with Yollies. The most prominent "young" sectors are the Internet sector and Biotech. All the firms in the Internet sector are born after 1990. In Biotech 91% of firms are Yollies. Other prominent "young" sectors are software (86% of leading innovators are young), semiconductors (71%), telecom equipment (64%), computer hardware (63%), computer services (64%). All these 'young' sectors are high-tech sectors. With the exception of computer hardware & services, their R&D intensity is above twice the total average in the sample. All these sectors also have an above average R&D growth rate.

Of the 363 Yollies in the sample, 218 are from the US, 59 are from the EU, 3 from Japan and 83 from the Rest of the Word.

--- INSERT TABLE 1 ABOUT HERE ---

Table 1 compares EU and US Yollies. Among the US's leading innovators in the R&D Scoreboard, more than half of them are Yollies. By contrast, Europe has only one out of five

[5] See for instance European Commission (2008).

[6] The geographic classification of firms is done on the basis of ownership. All activities of the firm are being consolidated in the R&D Scoreboard. We have no information on the geographic and sectoral distribution of firm's activities.

leading innovators as 'young'. For the US, Yollies account for 35 percent of total R&D, for the EU this is a mere seven percent! Yollies have a higher R&D intensity compared to their older counterparts in both regions. But for the US this is more evident, leaving a higher R&D intensity differential for US Yollies as compared to the EU. The differential in R&D intensity between European and US Yollies is strongly related to a differential sectoral distribution. Europe has fewer of its yollies in High-Tech sectors: 59% compared to 83% in the US[7].

4. Econometric analysis

To address why the EU has less R&D intensive young leading innovators and particularly in high-tech sectors, this section provides an econometric assessment of the rates of return for firms investing in R&D. We are interested in any differences between young and old firms, and between the US and the EU, particularly in high-tech sectors.

4.1. The econometric specification

Most of the econometric studies that have assessed rates of return to R&D adopt a general version of the Cobb-Douglas production function (Hall et al., 2010).

$$Y_{it} = \lambda t L_{it}^{\alpha} C_{it}^{\beta} K_{it}^{\gamma} e^{\varepsilon_{it}} \tag{1}$$

where: Y is output (value added or net sales[8]); L and C are the traditional inputs, i.e. labor and physical capital; K is the knowledge capital; α, β, and γ are the parameters of interest, i.e. the elasticities of output with respect to each of the inputs.

Usually equation (1) is taken in logarithm to implement the estimation of α, β and γ. This leads to the following linear regression model:

$$y_{it} = \lambda t + \alpha l_{it} + \beta c_{it} + \gamma k_{it} + \varepsilon_{it} \tag{2}$$

[7] For more descriptive analysis of Yollies, see Cincera and Veugelers (2012). For example, Cincera and Veugelers (2012) identify how much of the difference in R&D intensity between EU Yollies and their US counterparts is due to this different sectoral composition. They find that almost all of the difference (i.e. 98%) is due to a structural effect.

where lower case letters denote logarithms of variables. The parameter γ reflects the elasticity of output with respect to the R&D capital.

A difficulty raised by the Cobb-Douglas specification rests in the construction of the knowledge capital for the firm.[9] In order to get around this issue an alternative specification consists in directly estimating the rate of return to R&D instead of its elasticity (Griliches, 1973; Terleckij, 1974). Approximating the growth rate of variables in equation (1) by the first difference of their logarithms, assuming that the rate of depreciation of the R&D capital is close to zero, and given that by definition the elasticity of R&D with respect to output is equal to:

$$\gamma = \frac{\partial Y_{it}}{\partial K_{it}} \frac{K_{it}}{Y_{it}} = \rho \frac{K_{it}}{Y_{it}} \tag{3}$$

equation (1) expressed in growth rates, can be re-written as:

$$\Delta y_{it} = \lambda \Delta t + \alpha \Delta l_{it} + \beta \Delta c_{it} + \rho \frac{R_{it}}{Y_{it}} + \varepsilon_{it} \tag{4}$$

where ρ is the gross (i.e. net of depreciation) rate of return to R&D.

Estimating the elasticity of output with respect to R&D, with its requirement of constructing the firm's R&D capital stock is not well suited for our purpose as the time series available is not very long and its length is not the same from one firm to the other (i.e. the panel is unbalanced). Furthermore the depreciation rates for the R&D capital stocks across sectors and of Yollies and Ollies are probably not the same.

There are two other well-known problems when estimating the contribution of R&D. The first problem is the so called 'double counting' of R&D. This double counting arises since the conventional inputs generally already include the R&D-labor and R&D-capital components of

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[8] If sales is the left-hand variable, then materials should be added in the list of inputs. However, this last variable is not always available at the firm level. Value added is sometimes proxied by gross output, i.e. output less changes in inventories of finished goods.

[9] In general, the R&D capital stock is constructed on the basis of the perpetual inventory method and assuming a 15% depreciation rate of the R&D capital stock of the previous period common to all firms in the sample (Griliches, 1979). The stock of physical capital has been constructed using the same method with a 8% depreciation rate.

R&D expenditures. As shown by Schankerman (1981) and Mairesse and Hall (1996) for instance, this double counting reflects itself in downward estimates of R&D elasticities and rates of return. As a consequence, when the other inputs are not cleaned from their R&D components, the rate of return to R&D has to be interpreted as an excess rate.[10]

The second issue is related to the way output and inputs, including R&D investments have to be deflated. Price deflators are usually not available at the firm level and specifically for the various inputs. Also price deflators do not incorporate output quality changes and as a result underestimate the ‘real’ output (Mairesse and Hall, 1996). However, as Mairesse and Mohnen (1995) emphasize, with panel data, quality differences can be captured by time and sector dummies. However, there remain the inter-firm differences, which are not captured by these dummies. The R&D estimates are thus biased but only to the extent that sector prices or dummies do not fully capture the quality differences and the latter are correlated with the explanatory variables.

4.2. Econometric results

The major approach used and discussed in this contribution is the estimation of rates of return to R&D (equation (4)), rather than the R&D elasticities obtained through equation (2-3).

Tables 2 and 3 report the main findings of the econometric analysis of the links between R&D, traditional inputs and firms' productivity performance. In all specifications, we obtain estimated rates of return to R&D globally in line with the results generally reported in the R&D production function literature (Hall et al., 2010).

The second column of Table 2 exhibits the estimates of our benchmark median regression. The estimated rate of return to R&D obtained for the full sample of firms is equal to 0.048. Column 3 of Table 2 presents the estimated rates of return to R&D for the Yollies companies only. Yollies exhibit much higher rates of return to their R&D than the average firm. When an average company irrespective of its age invests one euro in R&D it receives, once we control

[10] Quoting Mairesse and Hall (1996: p.5), “Conceptually, the value added, labor, and capital measures used to estimate [the productivity equation] should be purged of the contribution of R&D materials, physical capital used in R&D laboratories, and R&D personnel, since these inputs do not produce current output, but are used to increase the stock of R&D capital. If this is not done, the cross section estimates [...] will not necessarily be incorrect, but the measured R&D coefficient will be some kind of ‘excess’ elasticity of output to R&D rather than a total elasticity, i.e. the incremental productivity of R&D rather than a total elasticity.”

for the other inputs, 5 cents in terms of additional generated output. For Yollies, this additional value amounts to 6 cents.

Table 3 also reports the results obtained for all firms in the EU and all firms in the US. While positive for the US firms, the rate of return to R&D of EU companies is not statistically significant for the average EU firm.

In terms of firms operating in high-tech sectors compared to medium- and low-tech sectors, only the former have a positive and significant rate of return.

--- INSERT TABLE 2 ABOUT HERE ---

We are particularly interested in any difference between the EU and the US in terms of rates of return for R&D investment for Yollies. The results presented in Table 3 allow one to examine this question. When comparing the estimated rates of return to R&D of all Yollies across regions, US Yollies exhibit higher rates of return (12 cents) compared to the average US firm (6 cents). For EU yollies, there are far fewer observations, reflecting the problem that Europe has less of these companies. Their estimated rates of return to R&D turn out to be not statistically significant. Hence, while in the US, Yollies exhibit significant rates of return to R&D, which are significantly higher than average, this cannot be established for European Yollies, who like their older counterparts, fail to exhibit significant rates of return to R&D.

Table 3 adds a further sectoral dimension by reporting the estimated rates of return to R&D of Yollies that operate in the high-tech sectors. Here also a higher rate of return (15 cents) is found for the Yollies compared to the average firms (9 cents). Results are also presented for EU and US high-tech Yollies. The rates of return to high-tech R&D US Yollies are clearly outperforming the other US firms (21 cents vs. 15 cents). For the EU companies, here also no direct comparison can be made as none of the estimates for rates of return to R&D are statistically different from zero, not for Yollies, but also not in general, even not in high-tech sectors.

--- INSERT TABLE 3 ABOUT HERE ---

4.3. Robustness tests

Table A1 in the Appendix compares the estimated rate of returns to R&D estimated from a simple OLS and median regression models. The estimated coefficients associated with the R&D intensity are much lower in the second model, i.e. 0.048, which can be explained by the presence of some outliers in the data.

Table A1 in the Appendix presents additional results based on GMM first difference (F.D.) and GMM system estimators (Blundell and Bond, 1998). These models allow one to control for the possible endogeneity of some of the regressors. [11] The Hansen over-identification test validates at the 5% level the set of instruments used (two and higher lagged values of regressors) only in the case of the GMM F.D. estimates. For this model, the rate of return associated with the R&D intensity is positive, albeit not statistically significant.

Table A2 in the Appendix reports the results of median regressions based on alternative specifications containing interaction terms between our variables of interest, i.e. R&D intensity and dummy variables representing the fact that a firm is a Yollie or not, is based in the EU or in the US, operates in a high-tech sector or not or a combination of these categories.[12] The results shown in Table A2 again confirm the higher rates of return to R&D for Yollies. This Yollies-premium only holds for the US.

The period under consideration (2000-2011) contains the crisis period from 2008. This crisis period, being a combined recession and financial crisis, may have affected young and old innovators differently and US firms differently from EU firms. Tables A.3 and A.4 report the results for the pre-crisis period only (2000-2007). It shows the negative effect from the crisis on the rates of return on R&D investment for all firms. But more importantly, although Yollies generate a higher rate of return on R&D than other firms, both before and after 2008, this Yollies premium was significantly higher pre-crisis, suggesting that R&D investments from Yollies are particularly crisis sensitive. This pre-crisis Yollies premium only prevailed in the US and particularly in high-tech sectors. Even pre-crisis, the rates of return to R&D for

[11] See Aldieri and Cincera (2009) for an application and discussion.

[12] One advantage of this type of specifications is that the sample of firms is held constant across models. Hence the differences in the estimated rates of returns to R&D are not due to differences in the samples' composition.

European Yollies, like for their older counterparts, already failed to show up significantly, even in high-tech sectors.

Table A5 in the Appendix provides results as regards the R&D elasticities for all firms in the sample. The elasticities associated with the stock of R&D[13] indicate a positive and important contribution of R&D to firms' productivity growth. The results based on the median regression are not very different than the ones we obtain with a simple OLS regression. The F-tests reject however the absence of firms' specific unobserved effects which may be correlated with the errors terms and as a result may bias the estimates. In order to accommodate for this situation, we also perform within and random panel data regressions (two last columns of Table A3). The Hausman test rejects the random model in favor of the within one, hence confirming the possibility of correlated unobserved effects with the disturbance terms. The estimated elasticities based on the within model and associated with the R&D stock are in line with OLS results: a one percent increase of the stock of R&D results in an increase of more than 0.15% of output (0.11% with the within-estimates).

The main findings of the econometric analysis can be summarized as follows. Yollies exhibit higher rates of return to R&D as compared to the average leading innovators. In particular US Yollies are performing better than the average US leading innovator (R&D rate of return twice as high). These results are to a large extent robust to alternative specifications and models.

In the next section, we discuss some implications of these results.

5. Concluding remarks

As EU's business R&D deficit with the US can be almost entirely explained by the EU having fewer young leading innovators and, even more importantly, having fewer of these in new high-R&D intensive sectors, it matters to understand why the EU has less young leading innovators and in high R&D intensive sectors. The results presented in this contribution suggest that the lower presence of young leading innovators and in the high R&D intensive sectors in Europe can be related to their non-significant rates of return to R&D as compared to their US counterparts. While in the US, young firms succeed in realizing significantly higher rates of

[13] The R&D stock is constructed on the basis of a Perpetual Inventory Method assuming a 15% depreciation rate.

return to R&D as compared to their older counterparts, including in high-tech sectors, European firms fail to generate significant rates of return, even if they are yollies and even if they are in high-tech sectors.

The evidence presented here, when corroborated in further analysis, has important implications for the EU's innovation policy agenda. In order for Europe to close its business R&D gap with the US, the evidence suggests that policies need to address the underperforming rates of return to R&D in Europe. To do this, policies need to particularly address the specific barriers to development of new high R&D-intensive sectors, as the evidence has shown how pivotal these sectors are for nations' dynamic performance. Perhaps the most pressing issue for tackling Europe's deficient capacity for change, are the missing higher returns to R&D which young leading innovators enjoy in the US. To address Europe's dynamic performance by invigorating young innovators, European policy makers should look beyond reducing administrative burden for innovative start-ups, to help boost the rates of return from R&D for young innovators even if they have succeeded to take up world innovative leadership.

Lower returns from innovation may not only hamper innovative firms from entering, growing, and developing a world innovative status, they may also reduce the appetite of those financing young risky highly innovative projects. Poorer rates of return relative to risk impede risk capital investing. If Europe wants to develop deeper risk capital markets, it needs to look beyond addressing the impediments on the supply side of risk capital to address the lower rates of return to R&D of risk capital projects in Europe.

How to address these lower rates of return? The analysis presented here cannot provide much help. It can only be at best speculative on possible causes for the lower rates of return and policy avenues in Europe relative to the US, relying on suggestions from the literature on the unique characteristics of the US innovation system (Mowery and Rosenberg, 1993; Freeman, 2001; Mowery, 2009). These suggested causes include a healthy breeding ground where new ideas can incubate before successful commercialization by spun-out entrepreneurs, access to early risk financing, access to risk-taking lead customers as well as access to frontier research, specialised know-how and skills, with anti-trust and procurement the most pivotal government instruments. Suggested policy avenues for Europe include the integration of the EU's risk capital, labour, product and (public) services markets, including activating procurement as demand side instrument and an innovation friendly enforcement of anti-trust.

However, at this stage of the analysis, when there are still too many unknowns about whether and which interventions are effective, more research is needed on causes and policy instruments. European policy-makers are advised to engage in closer monitoring of emerging innovative markets and evaluation of policy instruments to address gaps. “The early identification of major new waves of technological change of those features, which may facilitate or hinder their diffusion is the key to effective technology policies” (Freeman, 2001, p 123).

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Table 1: Yollies: EU versus the US

	EU	US	World Total
Share of Yollies in number of region’s leading innovators	23%	51%	34%
Share of Yollies in region’s leading R&D	4.5%	39.2%	18.7%
R&D intensity of Yollies	3.3	9.8	6.5
R&D intensity of Ollies	2.7	3.3	3.2
Share of the region’s Yollies in High-Tech Sectors	73.8	87.2	83.5
Share of the region’s Ollies in High-Tech Sectors	34.1	49.3	

Sources: Authors' own calculations on the basis of EU Industrial R&D Investment Scoreboard, EC, JRC/DG RTD and companies’ publicly available information

Table 2. Production function – All firms vs. Yollies; by region (EU vs. US) and by R&D intensity of sectors (high- vs. non high-tech sector)

Sample	All firms		Yollies		EU		US		High-Tech		Low+Medium-Tech	
Constant	-0.007	(0.005)	0.149	(0.011)	-0.051	(0.007)	-0.012***	(0.007)	-0.017**	(0.008)	-0.038*	(0.007)
Δ ln Employees	0.470*	(0.008)	0.488*	(0.012)	0.564*	(0.013)	0.489*	(0.011)	0.495*	(0.011)	0.440*	(0.011)
Δ ln Physical capital	0.307*	(0.016)	0.316*	(0.025)	0.207*	(0.026)	0.298*	(0.021)	0.293*	(0.021)	0.312*	(0.026)
R&D intensity	0.048*	(0.014)	0.061*	(0.021)	0.016	(0.022)	0.061*	(0.017)	0.078*	(0.017)	-0.145**	(0.064)
# of observations	7789		2331		2252		3225		4279		3510	
Pseudo R^2	0.23		0.21		0.21		0.28		0.23		0.23	

Notes: Least absolute deviation (median) regressions; *(**,***) = stat. significant at the 1% (5%, 10% level); standard errors in brackets; all equations include time dummies.

Table 3. Production function – All firms vs. Yollies; by region (EU vs. US) and by R&D intensity of sectors (high- vs. non high-tech sector)

Sample	Yollies &										High-tech &			
	EU		US		High tech		EU & High-tech		US & High-tech		EU		US	
Constant	-0.020	(0.034)	-0.049*	(0.013)	-0.033**	(0.013)	-0.039	(0.041)	-0.042*	(0.015)	0.004	(0.015)	-.028*	(0.010)
Δ ln Employees	0.605*	(0.044)	0.519*	(0.015)	0.502*	(0.014)	0.702*	(0.049)	0.524*	(0.017)	0.725*	(0.024)	0.468*	(0.014)
Δ ln Physical capital	0.260*	(0.080)	0.287*	(0.029)	0.342*	(0.029)	0.265*	(0.081)	0.316*	(0.033)	0.120*	(0.042)	0.349*	(0.028)
R&D intensity	0.015	(0.054)	0.120*	(0.027)	0.086*	(0.025)	0.064	(0.057)	0.125*	(0.031)	0.053***	(0.031)	0.107*	(0.023)
# of observations	383		1566		1907		284		1357		974		2183	
R^2	0.22		0.24		0.22		0.25		0.25		0.22		0.26	

Notes: Least absolute deviation (median) regressions; *(**,***) = stat. significant at the 1% (5%, 10% level); standard errors in brackets; all equations include time dummies.

Appendix – Table A1. Production function - Full sample – OLS, LAD, F.D. and SYS-GMM regressions

Method	OLS		LAD		F.D. GMM		GMM-SYS	
Constant	-0.032*	(0.010)	-0.007	(0.005)			-0.554	(0.394)
Δ ln Employees	0.345*	(0.051)	0.468*	(0.008)	0.609*	0.091	0.736*	(0.070)
Δ ln Physical capital stock	0.537*	(0.065)	0.307*	(0.016)	0.226**	0.110	0.290*	(0.057)
R&D intensity	0.243*	(0.073)	0.048*	(0.014)	0.051	0.059	-0.059	(0.049)
# of observations	7789				7754		9202	
R^2	0.25		0.23					
AR1 test					[0.001]		[0.000]	
AR2 test					[0.929]		[0.842]	
Sargan test					[0.000]		[0.000]	
Hansen test					[0.078]		[0.000]	

Notes: OLS = Ordinary Least square; LAD = Least absolute deviation (median) regression; F.D. GMM = First difference Generalized Method of Moments; SYS-GMM = System GMM; *(**,***) = stat. significant at the 1% (5%, 10% level); standard errors in brackets (robust for OLS); P-values in square brackets; instruments lagged 2, 3 and 4 periods; all regressions include time dummies; OLS and LAD regressions include country and industry dummies.

Table A2. Production function – interaction terms with Yollies, US and High-Tech

Sample	All firms		All firms		All firms		US		High-tech		US & high-tech	
Constant	0.143*	(0.005)	0.149*	(0.005)	-0.011***	(0.006)	-0.014***	(0.007)	-0.016**	(0.007)	0.162*	(0.010)
Δ ln Employees	0.464*	(0.008)	0.472*	(0.008)	0.475*	(0.007)	0.479*	(0.010)	0.486*	(0.011)	0.460*	(0.014)
Δ ln Physical capital	0.304*	(0.016)	0.303*	(0.017)	0.301*	(0.016)	0.312*	(0.021)	0.290*	(0.021)	0.339*	(0.028)
R&D intensity	-0.034	(0.028)	0.026	(0.023)	-0.181*	(0.070)	-0.040	(0.043)	0.002	(0.036)	0.003	(0.059)
Yollies	0.006***	(0.004)					0.005	(0.005)	0.011	(0.005)	0.010	(0.007)
US			-0.003	(0.003)								
High-tech					0.007	(0.005)						
R&D intensity x yollies	0.115*	(0.033)					0.162*	(0.048)	0.085**	(0.042)	0.123***	(0.065)
R&D intensity x US			0.036	(0.030)								
R&D intensity x high-tech					0.263*	(0.072)						
# of observations	7789						3225		4279		2183	
R^2	0.23		0.23				0.28		0.23		0.26	

Notes: Least absolute deviation (median) regression; *(**,***) = stat. significant at the 1% (5%, 10% level); standard errors in brackets; all equations include time dummies.

Table A.3. Production function - Pre-crisis period (2000-2007) - All firms vs. Yollies; by region (EU vs. US) and by R&D intensity of sectors (High- vs. non High-Tech sector)

Sample	All firms		Yollies		EU		US		High-Tech		Low+Medium-Tech	
Constant	0.010	(0.004)	0.022	(0.012)	-0.038	(0.005)	0.010	(0.004)	0.011	(0.007)	0.011	(0.005)
Δ ln Employees	0.467*	(0.008)	0.501*	(0.020)	0.595*	(0.012)	0.433*	(0.014)	0.483*	(0.013)	0.465*	(0.009)
Δ ln Physical capital	0.282*	(0.017)	0.271*	(0.036)	0.258*	(0.024)	0.301*	(0.024)	0.281*	(0.024)	0.265*	(0.020)
R&D intensity	0.070*	(0.014)	0.127*	(0.030)	0.020	(0.017)	0.088*	(0.020)	0.089*	(0.019)	-0.047	(0.059)
# of observations	4505		1431		1278		1909		2515		1990	
R^2	0.19		0.19		0.26		0.19		0.19		0.18	

Notes: Least absolute deviation (median) regressions; *(**,***) = stat. significant at the 1% (5%, 10% level); standard errors in brackets; all equations include time dummies.

Table A.4. Production function – Pre-crisis period (2000-2007) - Yollies by region (EU vs. US) and by R&D intensity of sectors (High- vs. non High-Tech sector); High-Tech firms by region (EU vs. US)

Sample	Yollies &										High-tech &			
	EU		US		High tech		EU & High-tech		US & High-tech		EU		US	
Constant	0.050**	(0.024)	0.058*	(0.013)	0.007	(0.014)	0.002	(0.029)	0.046	(0.015)	-0.032*	(0.011)	0.024*	(0.009)
Δ ln Employees	0.615*	(0.046)	0.505*	(0.022)	0.523*	(0.023)	0.750*	(0.054)	0.517*	(0.025)	0.713*	(0.024)	0.419*	(0.009)
Δ ln Physical capital	0.297*	(0.089)	0.281*	(0.036)	0.270*	(0.041)	0.215**	(0.095)	0.284*	(0.042)	0.187*	(0.048)	0.317*	(0.020)
R&D intensity	-0.010	(0.055)	0.176*	(0.033)	0.147*	(0.033)	0.042	(0.063)	0.205*	(0.038)	0.023	(0.029)	0.145*	(0.059)
# of observations	236		937		1174		177		811		560		1302	
R^2	0.23		0.20		0.19		0.26		0.21		0.25		0.19	

Notes: Least absolute deviation (median) regressions; *(**,***) = stat. significant at the 1% (5%, 10% level); standard errors in brackets; all equations include time dummies.

Table A5. Production function - Full sample – Elasticities of R&D

Method	OLS		LAD		OLS		LAD		Between		Within		Random	
Constant	-0.486*	(0.069)	-0.472*	(0.006)	-0.139	(0.093)	-0.224**	(0.106)	-0.723***	(0.372)	0.617*	(0.088)	-0.221*	(0.07
ln Employees	0.622*	(0.011)	0.614*	(0.005)	0.637*	(0.007)	0.641*	(0.008)	0.559*	(0.020)	0.678*	(0.009)	0.744*	(0.00
ln Physical capital	0.309*	(0.009)	0.308*	(0.006)	0.188*	(0.006)	0.203*	(0.007)	0.375*	(0.017)	0.023*	(0.005)	0.069*	(0.00
ln R&D capital	0.067*	(0.006)	0.077*	(0.006)	0.160*	(0.006)	0.146*	(0.007)	0.065*	(0.017)	0.114*	(0.011)	0.099*	(0.00
Industry and country dummies					X		X		X		X		X	
# of observations	9202													
R^2	0.89		0.71		0.92		0.75		0.90		0.57		0.57	
Hausman test											Chi²(13) 2278.50			

Notes: OLS = Ordinary Least square; LAD = Least absolute deviation (median) regression; *(**,***) = stat. significant at the 1% (5%, 10% level); standard errors in brackets (robust for OLS); P-values in square brackets; instruments lagged 2, 3 and 4 periods; all regressions include time dummies.

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